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ORIGINAL ARTICLE

Mid-upper-arm Circumference and Arm-to-height Ratio in Evaluation of Overweight and Obesity in Han Children

Qiang Lu, Rui Wang, Dong-Hui Lou, Chun-Ming Ma, Xiao-Li Liu, Fu-Zai Yin*

Department of Endocrinology, The First Hospital of Qinhuangdao, No. 258 Wenhua Road, Qinhuangdao 066000, Hebei Province, China

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Key Words
arm-to-height ratio;
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Background: The purposes of this study were: (1) to analyze whether mid-upper-arm circumference (MUAC) could be used to determine overweight and obese children and to propose the optimal cutoffs of MUAC in Han children aged 7—12 years; and (2) to evaluate the feasibility and accuracy of the arm-to-height ratio (AHtR) and propose the optimal cutoffs of AHtR for identifying overweight and obesity.
Materials and methods: In 2011, anthropometric measurements were assessed in a cross-sectional, population-based study of 2847 Han children aged 7—12 years. Overweight and obesity were defined according to the 2004 Group of China Obesity Task Force definition. The AHtR was calculated as arm circumference/height. Receiver operating characteristic curve analyses were performed to assess the accuracy of MUAC and AHtR as diagnostic tests for elevated body mass index (BMI; defined as BMI $\geq$ 85th percentiles).
Results: The accuracy levels of MUAC for identifying elevated BMI [as assessed by area under the curve (AUC)] were over 0.85 (AUC: approximately 0.934—0.975) in both genders and across all age groups. The MUAC cutoff values for elevated BMI were calculated to be approximately 18.9—23.4 cm in boys and girls. The accuracy levels of AHtR for identifying elevated BMI (as assessed by AUC) were also over 0.85 (AUC: 0.956 in boys and 0.935 in girls). The AHtR cutoff values for elevated BMI were calculated to be 0.15 in boys and girls.
Conclusion: This study demonstrates that MUAC and AHtR are simple, inexpensive, and accurate measurements that may be used to identify overweight and obese Han children.

* Corresponding author.
E-mail address: yinfuzai62@163.com (F.-Z. Yin).

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Compared with MUAC, AHtR is a nonage-dependent index with higher applicability to screen for overweight and obese children.

1. Introduction

In recent years, the prevalence of obesity has reached alarming levels, affecting both developed and developing countries and people of all socio-economic status, age, gender, and ethnicity.[1] Because of changes in childhood lifestyle characterized by the lack of physical activity and an energy-dense diet,[2] Chinese children have seen marked increases in the prevalence of childhood overweight and obesity over the past few decades.[3] The current epidemic of obesity with a subsequent increase in cardiovascular risk factors has constituted a threat to the health of school children in China.[4]

Appropriate early-stage diagnosis and intervention for overweight and obesity prevention in childhood are important for reducing the risk of obesity-related disorders. Body mass index (BMI) is the most common criteria used to determine overweight and obesity. The Working Group of Obesity in China established a set of age- and gender-specific cutoff points for BMI in 2004 for Chinese children and adolescents,[5] which were mainly based on ethnic Han children as the reference population. However, BMI fails to account for fat distribution.

As is well known, body-fat distribution is closely related to the occurrence and development of cardiovascular disease. Waist circumference is the most commonly used index of central adiposity. In China, waist circumference has been widely used to determine obesity in children. Reference values for waist circumference of Chinese children and adolescents have been provided by several epidemiological studies.[6,7] Recently, mid-upper-arm circumference (MUAC) has been proposed as another important indicator of obesity in children. Traditionally, MUAC has been commonly used in the assessment of nutritional status.[8] In 2003, de Almeida[9] et al suggested that MUAC was an adequate alternative method for obesity screening in preschool children.[9] This was proved by Mazıcıoğlu[10] et al in children aged 6—17 years.[10] Age-related MUAC cutoffs have been reported for children in two countries, Brazil[9] and Turkey,[10] but to our knowledge systematic monitoring of MUAC is not a commonly performed method in pediatric studies and clinical practice in China.

As for BMI, the age- and gender-specific standards of waist circumference and MUAC are less feasible for nonprofessional use. More recently, an increasing number of studies documented that the ratio of waist circumference to height [waist-to-height ratio (WHtR)] was an easy anthropometric index to detect obesity and cardiometabolic risk in children and adolescents.[11,12] A recent study has validated the suitability of WHtR to predict cardiovascular risk factors over direct body-fat measures, such as using dual-energy X-ray absorptiometry scanning and bioelectrical impedance analysis.[13] It is not known whether the ratio of arm circumference to height can identify overweight and obesity in children.

The purposes of this study were: (1) to determine whether MUAC can be used to diagnose overweight and obese children and propose the optimal cutoffs of MUAC in Han children aged 7—12 years; and (2) to evaluate the feasibility and accuracy of the arm-to-height ratio (AHtR) and propose the optimal threshold values of AHtR for identifying overweight and obesity. Han is the major Chinese ethnicity.

2. Materials and Methods

2.1. Participants

After obtaining informed consent from children and their parents, a cross-sectional, population-based study was conducted. The study population was determined according to two-stage cluster sampling. In the first stage, samples of primary schools in Qinhuangdao, China, were randomly obtained; and in the second stage, children aged 7—12 years in these schools were invited to participate. A total of 2847 Han children (1475 boys and 1372 girls) were included in the study population. All participants were required to be healthy. For this purpose, both a detailed medical history and a complete physical examination were performed prior to the study. The exclusion criteria were major medical conditions such as diabetes, Cushing's disease, thyroid diseases, and medication use. This study was approved by the ethics committee of the First Hospital of Qinhuangdao.

2.2. Anthropometric measurements

Anthropometric measurements, including height, weight, waist circumference, and MUAC were obtained while the participants were in light clothing and barefoot. Height and weight were measured to the nearest 0.1 cm and 0.1 kg, respectively. Waist circumference was accurately measured at the level of midway between the lowest rib and the top of the iliac crest. MUAC was measured using a flexible tape at the midway between the olecranon and acromial process on the upper right arm. All measurements were taken twice, and the two measurements were averaged for analysis. BMI was calculated by dividing weight (kg) by height squared (m^2). The WHtR was calculated as waist circumference/height and the AHtR was calculated as arm circumference/height.

2.3. Definition of overweight and obesity

Obesity was defined as BMI $\geq 95^{th}$ percentiles, overweight as BMI between the 85^{th} and the 95^{th} percentiles, and normal weight as BMI $< 85^{th}$ percentiles. The BMI cutoff values used were age- and gender-specific according to the

BMI cutoff references for Chinese children and adolescents.[5]

2.4. Statistical analyses

All analyses were performed using the SPSS version 11.5 (SPSS Inc., Chicago, IL, USA). Numerical variables were reported as mean ± standard deviation. Comparisons were made between the groups using the Student *t* test. The Pearson correlation coefficient was used to measure the strength of association between two variables. A *p* value <0.05 was taken to be significant.

Using receiver operating characteristic (ROC) analysis, ROC curves of MUAC and AHtR were drawn to show how well they could separate participants into groups with or without elevated BMI (BMI $\geq$ 85th percentiles). A test with an area under the curve (AUC) $\geq$0.85 is considered an accurate test.[14] Sensitivity and specificity of MUAC and AHtR have been calculated at all possible cutoff points to find the optimal cutoff values. The optimal sensitivity and specificity were the values yielding maximum sums from the ROC curves. Cutoff values and the corresponding AUC as well as the likelihood ratios [positive (LR+) and negative (LR−)] for MUAC that were predictive of overweight and obesity were computed along age and gender lines, and for AHtR they were computed along gender lines.

3. Results

According to the Group of China Obesity Task Force cutoffs, the prevalence rate of overweight and obesity in boys was 18.0% and 26.0%, respectively, whereas in girls it was 11.7% and 15.7%, respectively. The prevalence of overweight and obesity was significantly higher in boys than in girls ($p < 0.001$).

Age and anthropometric data are presented in Table 1. The ages of boys and girls were similar ($p > 0.05$). The BMI and waist circumference were significantly higher in boys than in girls ($p < 0.001$). Both mean MUAC (20.9 ± 3.7 cm vs. 20.2 ± 3.2 cm, $p < 0.001$) and mean AHtR were higher in boys than in girls (0.148 ± 0.021 vs. 0.143 ± 0.019, $p < 0.001$).

Table 2 presents the Pearson correlation coefficients between MUAC, AHtR, and clinical and anthropometric parameters for boys and girls. MUAC showed a strong positive correlation with BMI, waist circumference, and WHtR ($p < 0.001$). AHtR showed a strong positive correlation with BMI, waist circumference, WHtR, and MUAC ($p < 0.001$). The correlation between AHtR and age ($r = 0.048$, $p = 0.063$ for boys and $r = -0.043$, $p = 0.109$ for girls) was much weaker than the correlation between MUAC and age ($r = 0.384$, $p < 0.001$ for boys and $r = 0.382$, $p < 0.001$ for girls). MUAC showed a strong positive correlation with height ($p < 0.001$). In addition, the correlation was seen for both boys and girls and across all age groups ($p < 0.001$). As shown in Table 3, the positive correlation between AHtR and height was much weaker than the correlation between MUAC and height, especially in girls.

The abilities of MUAC to accurately define elevated BMI were assessed by AUC. The AUC of MUAC was not significantly different from the AUC of waist circumference for both boys and girls and across all age groups ($p > 0.05$). Table 4 shows that for both ages and genders, the accuracy levels of MUAC for identifying elevated BMI (as assessed by AUC) were >0.85 (AUC: approximately 0.934–0.975). The MUAC cutoff values for elevated BMI were calculated to be approximately 18.9–23.4 cm in boys and girls. The sensitivities were approximately 82.5–90.2% in boys and approximately 83.6–94.5% in girls. The specificity was approximately 89.0–95.7% in boys and approximately 81.7–94.0% in girls. The likelihood ratios for each cutoff point are also shown in Table 4.

The AUC of AHtR was not significantly different from the AUC of WHtR for both boys and girls ($p > 0.05$). Table 5 shows that for both genders, the accuracy levels of AHtR for identifying elevated BMI (as assessed by AUC) were >0.85 (AUC: 0.956 in boys and 0.935 in girls). The AHtR cutoff values for elevated BMI were calculated to be 0.15 in boys and girls. The sensitivities were 86.0% in boys and 85.4% in girls. The specificities were 91.5% in boys and 87.8% in girls. The likelihood ratios for each cutoff point are also shown in Table 5.

Table 1 General characteristics of the study population.

Variable	Boys (n = 1475)	Girls (n = 1372)	p
Age (y)	9.4 ± 1.6	9.5 ± 1.5	0.567
Weight (kg)	40.0 ± 13.7	37.0 ± 11.8	<0.001
Height (cm)	141.3 ± 11.3	140.8 ± 11.4	0.249
BMI (kg/m^2)	19.5 ± 4.5	18.2 ± 3.7	<0.001
WC (cm)	67.4 ± 11.8	63.0 ± 9.7	<0.001
MUAC (cm)	20.9 ± 3.7	20.2 ± 3.2	<0.001
WHtR	0.476 ± 0.066	0.447 ± 0.054	<0.001
AHtR	0.148 ± 0.021	0.143 ± 0.019	<0.001

AHtR: arm-to-height ratio; BMI = body mass index; MUAC = mid-upper-arm circumference; WC = waist circumference; WHtR = waist-to-height ratio; y = years.

4. Discussion

This study discusses the use of MUAC in the evaluation of overweight and obese Han children aged 7–12 years. The MUAC was closely associated with BMI and waist circumference for both boys and girls. Thus, MUAC can accurately identify overweight and obesity in Han children. The areas under the ROC curve of approximately 0.934–0.975 were consistent with robust diagnostic performance and indicated that measurement of MUAC has a powerful ability to identify children with or without elevated BMI. This study provides the first MUAC cutoff values for Han children aged 7–12 years. The MUAC cutoff values increase with age and are similar between boys and girls.

Waist circumference is considered as the best indicator of abdominal obesity,[15] and it is associated with metabolic syndrome, insulin resistance, and biomarkers of vascular smooth muscle dysfunction in children.[16–18] However, the measurement of waist circumference is affected by respiratory movements and postprandial abdominal distension. The measurement of MUAC is independent of these factors and may therefore be an alternative and reliable index. In

Table 2 Relationship between mid-upper-arm circumference, arm-to-height ratio, and other anthropometric variables by gender.

Variable	MUAC				AHtR			
	Boys		Girls		Boys		Girls	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Age	0.384	<0.001	0.382	<0.001	0.048	0.063	−0.043	0.109
Height	0.599	<0.001	0.527	<0.001	0.186	<0.001	0.015	0.586
Weight	0.904	<0.001	0.858	<0.001	0.670	<0.001	0.520	<0.001
BMI	0.909	<0.001	0.893	<0.001	0.857	<0.001	0.772	<0.001
WC	0.924	<0.001	0.865	<0.001	0.802	<0.001	0.656	<0.001
WHtR	0.795	<0.001	0.725	<0.001	0.882	<0.001	0.805	<0.001
MUAC	1	—	1	—	0.896	<0.001	0.855	<0.001

AHtR = arm-to-height ratio; BMI = body mass index; MUAC = mid-upper-arm circumference; WC = waist circumference; WHtR = waist-to-height ratio; y = years.

our study, the AUC of MUAC or waist circumference was similar in both genders and across all age groups, indicating that these two measures have similar accuracy in identifying overweight and obesity in Han children.

Direct measurement of body-fat content and distribution, for example, dual X-ray absorptiometry, is also used as an accurate measure of obesity, but such methods are neither practical nor inexpensive. Chomtho et al[19] reported that MUAC correlated strongly with fat mass but weakly with fat-free mass. The MUAC value explained 63% of variability in total fat mass and only 16% of variability in total fat-free mass in healthy children.

Table 3 Relationship between mid-upper-arm circumference, arm-to-height ratio, and height by age and gender.

Age (y)	MUAC				AHtR			
	Boys		Girls		Boys		Girls	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*
7	0.493	<0.001	0.400	<0.001	0.261	<0.001	0.069	0.352
8	0.574	<0.001	0.388	<0.001	0.323	<0.001	0.048	0.463
9	0.580	<0.001	0.437	<0.001	0.290	<0.001	0.123	0.055
10	0.580	<0.001	0.461	<0.001	0.315	<0.001	0.142	0.017
11	0.472	<0.001	0.393	<0.001	0.170	0.004	0.063	0.334
12	0.405	<0.001	0.310	<0.001	0.085	0.244	0.053	0.473

AHtR = arm-to-height ratio; MUAC = mid-upper-arm circumference.

Table 4 Area under the curves, optimal cutoff values, sensitivities, and specificities for mid-upper-arm circumference associated with overweight/obesity in boys and girls.

Age (y)	*n*	AUC (95% CI)	*p*	Cutoff	Sensitivity (%)	Specificity (%)	LR+	LR−
Boys								
7	208	0.934 (0.898−0.970)	<0.001	18.9	87.7	89.0	7.97	0.13
8	267	0.965 (0.947−0.984)	<0.001	19.6	90.2	91.5	10.61	0.10
9	264	0.967 (0.948−0.986)	<0.001	21.1	87.1	95.7	20.25	0.13
10	271	0.963 (0.944−0.982)	<0.001	21.9	89.2	90.9	9.80	0.11
11	277	0.940 (0.912−0.968)	<0.001	22.6	82.5	93.0	11.78	0.18
12	188	0.971 (0.951−0.990)	<0.001	23.4	89.2	91.4	10.37	0.11
Girls								
7	184	0.943 (0.909−0.977)	<0.001	18.9	90.6	81.7	4.95	0.11
8	237	0.975 (0.958−0.991)	<0.001	19.6	94.5	88.5	8.21	0.06
9	246	0.956 (0.926−0.987)	<0.001	20.4	94.2	88.1	7.91	0.06
10	284	0.959 (0.935−0.983)	<0.001	21.9	92.1	89.7	8.94	0.08
11	238	0.944 (0.905−0.982)	<0.001	22.6	83.6	93.2	12.69	0.17
12	183	0.961 (0.919−1.003)	<0.001	23.4	91.8	94.0	15.30	0.08

AUC = area under the curve; CI = confidence interval; LR+ = positive likelihood ratios; LR− = negative likelihood ratios.

Table 5 Area under the curves, optimal cutoff values, sensitivities, and specificities for arm-to-height ratio associated with overweight/obesity in children.

Gender	*n*	AUC (95% CI)	*p*	Cutoff	Sensitivity (%)	Specificity (%)	LR+	LR−
Boys	1475	0.956 (0.946−0.966)	<0.001	0.15	86.0	91.5	10.11	0.15
Girls	1372	0.935 (0.920−0.950)	<0.001	0.15	85.4	87.8	7.00	0.16

AUC = area under the curve; CI = confidence interval; LR+ = positive likelihood ratios; LR− = negative likelihood ratios.

In addition, the prevalence and rate of diagnosis of hypertension in children and adolescents appear to be increasing.[20] This is due in part to the increasing prevalence of childhood obesity. Obesity increases the occurrence of hypertension threefold while favoring the development of insulin resistance, hyperlipidemia, and salt sensitivity.[21] Correct measurement of blood pressure in children requires use of a cuff that is appropriate to the size of the child's MUAC.[22,23]

An ideal measurement method for childhood obesity should meet the following criteria: the method should be simple, inexpensive, easy to use, and acceptable to the participants. While evaluating the obesity index, WHtR has several key advantages: it is easy to calculate, does not require gender- and age-specific percentiles, and can be easily understood by clinicians and families.[24] Similar to WHtR, AHtR also has several advantages in practice for identifying overweight and obese Han children. First, AHtR is not correlated with age, which makes it possible to propose nonage-dependent cutoff points (as we did in our study), which are easy and feasible to manipulate for both professionals and lay people. These results could be due to the fact that AHtR was already adjusted by height, which is strongly correlated with age. By contrast, the correlation with MUAC was less weak because MUAC was not adjusted by height. Second, height is simultaneously taken into account. For the pediatric population, growth is a very important factor for body composition change, and therefore, age and height should always be taken into account. In each gender and age group, MUAC all showed a strong positive correlation with height. This result is consistent with a recent study in Turkish children.[25] Referring to age- and gender-specific references should prevent mislabeling tall children who are not overweight or missing a diagnosis of overweight or obesity in short children, as was the case when only a single value for MUAC was used for each age. The AHtR can prevent misdiagnosis, as the AHtR of children with the same gender, age, and MUAC was lower in tall children than in short children. Third, AHtR was still associated with BMI. By using the same threshold of 0.15 for elevated BMI in boys and girls, we can obtain sensitivity and specificity of over 80% (85.4−91.5%). In our study, both AHtR and WHtR were performed in order to identify overweight and obese children.

The main limitation of our study was that it included children only of Han ethnicity, limiting the ability to apply the study results to other ethnic groups. However, many studies have shown that body size is an essential determinant of MUAC in children, and so it is necessary to include the child's height to determine whether MUAC is normal.[26,27] Height-dependent standards have been developed by the World Health Organization for identifying malnutrition, which are generally accepted.[28] Thus, we speculate that this method could be applied to other ethnic groups. Another limitation was the lack of data on preschool children and adolescents. In future studies, we will analyze the feasibility of this method by applying it in preschool children and adolescents.

We conclude that both MUAC and AHtR are simple, inexpensive, and accurate indexes for identifying overweight and obese Han children. Compared with MUAC, AHtR is a nonage-dependent index with higher applicability to screening for overweight and obesity in children. Our MUAC and AHtR cutoffs, which correctly identified the majority of children with high BMI, could be used as a reference for boys and girls aged 7−12 years.

Conflicts of Interest

The authors declare that they have no financial or nonfinancial conflicts of interest related to the subject matter or materials discussed in the manuscript.

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